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Evaluation of the FIBROSAMPLER and the DIGITAL FIBROGRAPH for Sampling COTTON FIBERS and Measuring Length Characteristics

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Preface

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EVALUATION of the FIBROSAMPLER and the DIGITAL FIBROGRAPH for SAMPLING COTTON FIBERS and MEASURING LENGTH CHARACTERISTICS

By Frances Carpenter, *cotton technologist*
Market Quality Research Division
Agricultural Research Service
U.S. Department of Agriculture

Summary

This is a progress report on the evaluation of the Fibrosampler for sampling cotton fibers, and the Digital Fibrograph for measuring length and length distribution of the fibers, and the relationship of these measurements to processing performance and product quality. Three series of samples were tested: one consisted of several varieties of cotton which had a wide range of fiber properties; each of the other two series was a single variety with samples differing in length and length distribution due to ginning treatments. No comparable spinning data were available for the first series of samples.

The Fibrosampler is a practical instrument when properly used. Specific techniques of operation are essential if the variation is to be kept at a minimum. In spite of the careful application of the techniques which appear in this report, a significant difference in level was found between technicians. This is a common occurrence where tests are not completely objective. The preparation and kind of sample also contribute to variation in specimens and to the time required for their preparation.

The Fibrosampler has a tendency to select long fibers; however, hand-combed specimens of long cotton were longer than Fibrosampler specimens of the same cotton.

The Digital Fibrograph, Model 230, is a highly efficient and stable instrument which can measure one specimen per minute when readings are made at the 2.5 percent and 50 percent span lengths. When the simulated sample was used as a specimen, repeatability for 50 consecutive readings was 0.10 percent for each of these span lengths, and repeatability over a 9-month period was 0.18 percent for the 2.5 percent span length and 0.45 percent for the 50 percent span length. For some cottons, difficulty was experienced in the selection of the exact point at which to read the 2.5 percent span length because there was not always a definite point of balance where the counters stopped. The six lamps in the lighthouse of the Digital Fibrograph can contribute to error, especially when imperfect specimens are used.

The Fibrosampler-Digital Fibrograph combination is very efficient for measuring cotton fiber length. The array test is not practical for use in commercial channels, but it was used to furnish a datum level for the evaluation of the Digital Fibrograph measurements. Test efficiency, as used in this report, involves sensitivity to sample differences and the repeatability of the measurements. When range of length was small, the 2.5 percent span length was a more efficient test than array upper quartile length; but both array coefficient of length variability and array percentage of fibers shorter than one-half inch were more efficient than the Digital 50 or 66.7 percent span lengths; and the 50/2.5 uniformity ratio was the least efficient of all of these measures. Array percentage of fibers shorter than one-half inch seemed to be a more efficient test than array coefficient of length variability or the Digital measurements. When the range of length was great, array measurements were more sensitive to sample differences and were more efficient tests than the Digital measurements.

For carded yarn, array mean length was more highly related to break factor and end breakage than any of the length measurements. The Digital 2.5 percent span length explained as much of the variation in break factor as array upper quartile length or Servo upper half mean length. Array coefficient of length variability, array percentage of fibers shorter than one-half inch, and Digital span lengths were significantly better than the Servo uniformity ratio as indicators of spinning end breakage. Each of the Digital span lengths was better than array

measurements in explaining variation in the spinning potential yarn number.

None of the experimental measurements of length and length distribution proved to be more valuable in explaining variation in spinning test results than the 2.5 percent and 50 percent span lengths. The 50 percent span length seemed to be more highly related to spinning performance than the 50/2.5 uniformity ratio.

For combed yarn, the Digital 2.5 percent span length for ginned lint, card sliver, and comber sliver explained as much of the variation in break factor as the array upper quartile length. Array percentage of fibers shorter than one-half inch, array coefficient of length variability, and Digital 50 percent span length explained as much of the variation in break factor as the 2.5 percent span length or array upper quartile length. Digital and array measurements of length distribution for the ginned lint seemed to be of equal significance in explaining end breakage, but array percentage of fibers shorter than one-half inch for card and comber sliver was significantly better than the 50/2.5 uniformity ratio.

A high degree of relationship existed between span lengths, hence a high degree of similarity between their relationships to spinning. These relationships are due to built-in factors for measurements obtained by scanning fiber beards, as well as to the source and selection of samples.

The magnitude of testing error seems to be related to length. Testing error coefficient of variation decreased with an increase in span length. A comparison of testing errors for lint, card sliver, and comber sliver showed tests from comber sliver to be more variable, probably due to the difficulty in obtaining representative specimens with the Fibrosampler from highly oriented fibers.

For comber noils, array upper quartile length was more sensitive to sample differences than the 2.5 percent span length, but the 50 percent span length and the 50/2.5 uniformity ratio were more sensitive to sample differences than array coefficient of length variability. Array percentage of fibers shorter than one-half inch was the most sensitive of the measurements of length distribution of comber noils.

Background and Purpose of the Study

Industry and various research organizations need more objective methods for measuring and describing inherent cotton fiber characteristics which affect the marketing, manufacturing, and quality of cotton products. Much progress has been made in the field of fiber technology in the past 30 years. Adequate methods and instruments for commercial testing of cotton fiber fineness have been developed, but present methods for measuring length and length distribution and fiber tensile strength do not appear to be entirely satisfactory from a production standpoint. Length distribution is of great importance in processing cotton yarn *(4, 7)*.[1]

Another area in need of investigation is that of sampling. Too much emphasis cannot be placed upon the importance of representative sampling to the value of any test made on cotton fibers. There is a wide variation in fiber properties within a bale of cotton, and obtaining a small representative sample is a difficult assignment. Careful techniques are also required in the selection of test specimens.

The Fibrosampler and the Digital Fibrograph are the two most widely used instruments for obtaining length parameters of cotton fibers. These two instruments are the results of the efforts of many technologists working together over a period of more than 20 years. In 1940, Hertel (*5*) reported on the theory and application of the first Fibrograph, which was manually operated, and specimens were prepared by hand combing. Tallant, in 1952 (*10*) and 1958 *(11)*, suggested modifications resulting in the Servo Fibrograph. Rouse (*8*) developed the principle of precise measurements made at selected points by dial gauges to measure the movement of the comb holder (length of fibers) and the card holder (number of fibers). The elimination of fibrogram-tangent drawing to obtain length values reduced variation by one-half.

Later, digital counters took the place of the dial gauges, and with the installation of an appropriate pushbutton system, the Digital Fibrograph became automatic (*3*). A number of laboratories cooperated with Dr. Hertel in the evaluation of this model. Rouse[2] reported that "the 2.5 percent span length (*6*) and the 50/2.5 uniformity ratio affected spinning results to a greater extent than any other length values." His report was made after he had investigated several starting points and points to be measured.

The Fibrosampler-Digital Fibrograph com-

[1] Italic numbers in parentheses refer to Literature Cited, page 14.

[2] ROUSE, J. T. PROGRESS REPORT OF DIGITAL FIBROGRAPH. Paper presented at the American Cotton Manufacturer's Institute Open House, Clemson, S. C., May 3–4, 1961.

bination was given a favorable appraisal from the mill viewpoint by Hall (*4*), using cottons which had been screened by experienced cotton classers. Most Fibrograph owners have continued to make measurements at the 2.5 percent and 50 percent span lengths. However, many are experimenting and collecting data in an effort to find better values for their own particular operations and products.

This study is part of a program of instrument evaluation, partially supported by the National Cotton Council. The purpose of this program is to aid in the development of more efficient means of determining cotton quality.

The purpose of this study is to evaluate the Fibrosampler as a sampling device and the Digital Fibrograph for measuring length and length distribution and to relate these measurements to processing performance and product quality.

Description of Instruments

Fibrosampler.—The Fibrosampler is a mechanical device designed to extract a representative test specimen from a sample of cotton fibers and prepare a fiber beard to be measured on the Digital Fibrograph. A sample of cotton is placed inside the cylinder of the Fibrosampler. When pressure is applied to the sample, the fibers protrude through the perforations. When the pivot arm is rotated with a comb in place, fibers are caught on the comb teeth and are combed as one rotation is completed. The comb clamp is then closed, thereby clamping the fibers on the comb. A second comb is prepared in the same way and the beards of fibers on the two combs are ready to be measured on the Digital Fibrograph as one specimen.

The Digital Fibrograph. — Transistorized Digital Fibrograph (Model 230) was evaluated. This model has six incandescent lamps equally spaced in the lighthouse. Recommended measurements to be made with this instrument are the 2.5 percent and 50 percent span lengths, using the number at 0.150 inch as 100 percent. The 50/2.5 uniformity ratio is a ratio between the 50 percent and the 2.5 percent span lengths and is used as a measurement of length distribution.

"Two combs holding sample beards of cotton are placed on the comb carrier in such a position that a narrow beam of light from a light source passes through the beards and into a pair of photoelectric tubes. The absorption of light by the beard is a measure of the number of fibers contained in the sample at the point where the light beam passes through the sample" (*1*).

Additional information concerning the construction, optics, etc., of the Digital Fibrograph may be found in the SpinLab Instruction Manual (*1*).

Samples Tested

Three series of samples were tested for these evaluation studies. Series I consisted of 25 samples having a wide range of fiber properties and representing several varieties of cotton. The samples were selected on the basis of array data and varied in upper quartile length (UQL) from 1.04 to 1.35 inches and in array coefficient of variability (CV) from 25 to 39 percent. Because of the wide range in length, these samples were not spun using the same spinning organization; hence, no comparable spinning data were available. Servo Fibrograph data were available.

Series II consisted of 25 samples from a ginning-spinning study. The samples varied in length and length distribution due to harvesting and ginning treatments. Array UQL varied from 1.21 to 1.31 inches and array CV from 26 to 34 percent. Servo Fibrograph data and comparable spinning data for 50s carded yarn were available for these samples.

Series III consisted of 69 samples from a ginning-spinning study. Array UQL varied from 1.27 to 1.39 inches and array CV from 26 to 39 percent. Servo Fibrograph data and comparable data from 60s combed yarn were available.

All tests were performed under standard atmospheric conditions.

Development of Testing Techniques for the Fibrosampler

Hertel gave the requirements for specimens to be measured on the Fibrograph. "Preparation of a sample of cotton for length measurements requires random catching of fibers, placing them in a clamp, removing all of the loose, unclamped fibers, and paralleling the fibers into a beard" (*6*).

Very limited instructions for the operation of the Fibrosampler were supplied by the manufacturer. In an attempt to prepare a sample

with the Fibrosampler, many suggested techniques were investigated and a standard procedure for specimen preparation was developed for use in this evaluation study. Essential techniques and reasons for their selection included the following:

1. "Pressure should be evenly distributed across the sample" (*1*). Evenly applied pressure is necessary for obtaining satisfactory specimens. The amount of pressure determines the amount of cotton that will be caught on the comb, and practice is necessary in learning the amount of pressure to use for a specimen of proper size. Uneven pressure results in a beard that varies in density.

2. "Gently and slowly rotate the pivot arm" (*1*). Gentle and slow rotation of the pivot arm prevents fiber breakage. It should not be necessary to use great force. Increased speed of rotation caused an increase in length variation resulting from fiber breakage. With good samples, specimens can be prepared as rapidly as they can be measured by the Digital Fibrograph.

3. To take a specimen, fill at least one-half of the perforations on the Fibrosampler cylinder with the sample of cotton. The 2.5 percent span lengths were longer when all of the perforations were filled than when only one-fourth of the perforations were filled. More uniform results were obtained when at least one-half of the perforations were filled.

4. Satisfactory specimens cannot have holes or thick and thin places which fall under one or more of the six lamps in the lighthouse. Erroneous results are obtained from poor specimens (fig. 1). Apparent span lengths increased with an increase in the size of holes, and the 50/2.5 uniformity ratio showed the cotton to be more uniform than it really was. Holes totaling ½ inch in width can increase the 2.5 percent span length by $\frac{1}{32}$ inch and the 50/2.5 uniformity ratio by 6 percentage points.

5. Use a fresh sample surface for each comb. The combs tend to select long fibers, as was shown by making a series of tests of four specimens each without changing the surface. The test averages were successively shorter in span length, showing that more long fibers were taken out on earlier sampling.

6. A "broken" surface with loose fiber ends facilitates satisfactory specimen preparation. The condition of the surface, or preparation of the cotton, affects the kind of beard obtained.

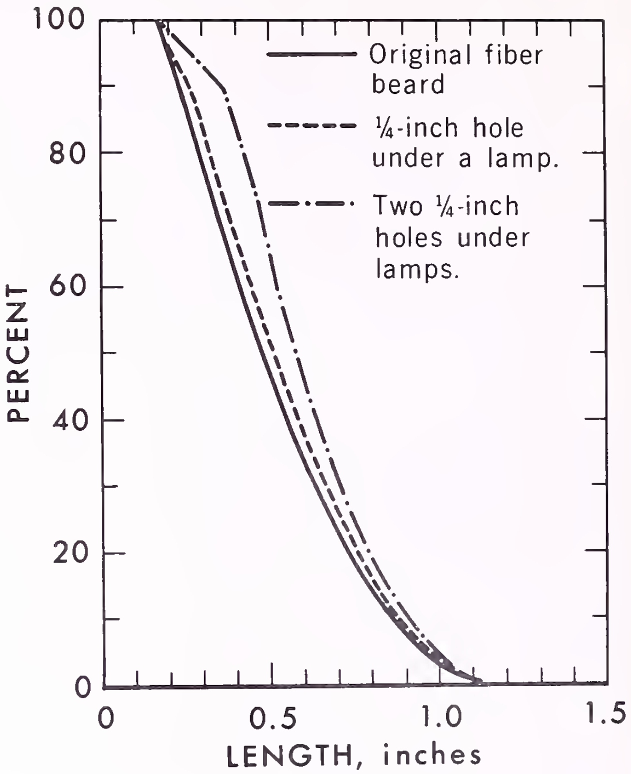

FIGURE 1.—The effect of holes in the fiber beard.

If the sample is fluffy and does not contain trash, motes, etc., satisfactory specimens are easily obtained. Stringy cotton, recently compressed cotton, or processed cotton may give difficulty. Card sliver and comber sliver require special attention. Card sliver was blended on the fiber blender to disorient the fibers from sliver form. But span length was shortened by fiber breakage during blending, and the blending procedure was eliminated.

7. Three or four firm rolling strokes with the recommended brush are usually sufficient to remove trash and loose fibers after the specimen has been placed on the Digital Fibrograph. Insufficient brushing caused an increase in variation. Too much brushing increased the 2.5 percent span length and loosened the fibers in the combs. To prevent erroneous measurements, neps and trash not removed during brushing should be removed with tweezers.

8. Have two technicians work together; that is, one to prepare specimens while the other operates the Digital Fibrograph. Variation between specimens decreased when specimen preparation was a continuous operation.

Length Distribution in the Fibrosampler Specimen

An effort was made to determine the length and length distribution of the fibers in the Fibrosampler specimen (1) as measured by the Fibrograph and (2) by array-type measurements made on the sheared beards of the same specimens. Four specimens were prepared with the Fibrosampler and measured on the Digital Fibrograph. One fibrogram was drawn from the average of these measurements. The same specimens were sheared from the combs and array-type measurements were made, data were averaged, and a number-length curve (second accumulation) was constructed. A comparison of the two curves shows the Fibrograph measurements to be shorter; however, the Fibrosampler specimen seems to be a second integral of the distribution of length in the original sample (fig. 2). Hertel (*5*) has described measurements from scanning specimens of unclamped, combed fibers as being the second accumulation of the length distribution of the original sample. The removal of crimp while making the array-type measurements probably accounts for the length differences in the long-fiber region. The third curve in the diagram is the number-length curve constructed from the average of 15 standard array tests on the same cotton as that used with the Fibrosampler. Specimens for array tests have considerably longer measurable fibers than Fibrosampler specimens from the same cotton. Since fibers in the Fibrosampler specimen and, also, hand-combed specimens for the Fibrograph are "caught at random points along their lengths" by the teeth of the combs, it is obvious that measurements made from the comb to the fiber tips would be shorter than the fiber length from tip to tip.

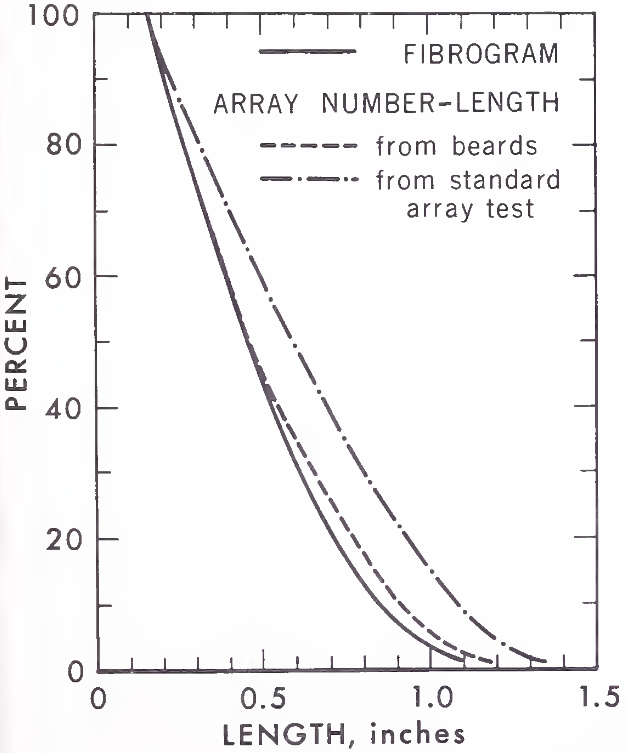

FIGURE 2.—Comparison of the fibrogram and array number-length curve for the same fiber beards.

Yoakum,[3] with earlier models of the Fibrosampler and Digital Fibrograph, found that Fibrosampler specimens gave a longer 3 percent span length than hand-combed specimens.

Rouse [4] found the 2.5 percent span length for Fibrosampler specimens and Servo upper half mean length (UHM) from hand-combed specimens to be essentially equal for 443 medium staple samples in the 1960 Annual Quality Survey. He also found that "variability between observations of blended samples in these tests was slightly less for the specimens prepared by the Fibrosampler than the variability for specimens prepared manually, but this was reversed for unblended samples." Since he found that blending lessened variation only slightly, it was thought that the time required for blending was not justified for this evaluation study, and all tests using the Fibrosampler were performed on unblended samples.

Fibrosampler specimens measured on the Model 230 Digital Fibrograph and compared with Servo Fibrograph measurements of hand-combed specimens were shorter for two series of cotton, but slightly longer for the series with a wide range of fiber properties:

	Hand-combed specimens, Servo UHM	*Fibrosampler specimens, Digital 2.5 percent span length*
	Inches	*Inches*
Series I	1.072	1.086
Series II	1.101	1.087
Series III	1.176	1.155

These differences may indicate a change in level of length for hand-combed specimens of long cotton due to the combing technique. All Fibrosampler specimens receive the same amount of combing—that achieved by one rotation of the pivot arm.

[3] YOAKUM, ROGER L. PRELIMINARY EVALUATION OF THE DIGITAL FIBROGRAPH AND FIBROSAMPLER. U.S. Dept. Agr. [Unpublished report.] 1959.

[4] See footnote 2.

Precision, Stability, and Speed of the Digital Fibrograph

Instrument precision was determined from measurements made on each of several kinds of specimens: (1) The simulated sample used in calibrating and daily checking the instrument, (2) a hand-combed specimen which was cemented in place, read 50 times one day, and 10 times a day for 5 days, and (3) Fibrosampler specimens of card web from a thoroughly mixed bale.

The results of these tests showed the repeatability of the Fibrograph to be very good (table 1). Instrument repeatability for the 2.5 percent span length was within 0.10 percent when the simulated sample was used as a specimen for 50 consecutive readings. Readings made in daily calibration of the instrument over a period of 9 months varied 0.18 percent for the 2.5 percent span length and 0.45 percent for the 50 percent span length. Repeatability was not as good for the specimens of cotton, but in the light of the above results, the variability was probably due to specimens and not the Digital Fibrograph. The variation was approximately one-half that expected in normal testing of check test cottons. The effect of crimp, the removal of some of the loose, unclamped fibers in the specimen, and the selection of the point at which the 2.5 percent span length should be recorded cause variation, in addition to those factors discussed in the techniques for specimen preparation. At the 2.5 percent span length the counter races past the actual length, then rolls back to balance. This point of balance is not always clear or obvious. For some cottons there was a difference of 0.04 inch between the highest reading and the lowest one. The balance point at shorter span lengths was not a problem.

These data were analyzed by analysis of variance to show sensitivity to sample differences as CV of lot means and repeatability as CV of error of individual observations. Both of these types of variation affect the efficiency of a test measurement. If two measurements of fiber length such as array UQL and Digital 2.5 percent span length are compared, the test with the greater CV of lot means is the more efficient one if the CV's of error are very similar; or, the test with the lower CV of error is the more efficient if the CV's of lot means are similar. It was necessary to use a ratio between the two kinds of variation for comparing test efficiency. Comparisons of means, sensitivity, and repeatability may be made for Series I and Series II samples (table 2).

When the range of length was great (Series I): (1) array measurements were more sensitive to sample differences than the Digital measurements; (2) when both sensitivity and repeatability were considered, the array UQL was a more efficient test than the 2.5 percent span length; (3) the 50 percent and 66.7 percent span lengths were more efficient tests than the 50/2.5 uniformity ratio; (4) the 50 percent span length was better than the 66.7 percent span lengths; and (5) array CV and SF (percentage of fibers shorter than ½-inch) were very similar in efficiency and both were more efficient tests than the Digital measurements.

TABLE 1.—*Repeatability of the Digital Fibrograph using the simulated sample, a specimen of cotton, and specimens of card web*

Sample	Number of measurements	2.5 percent span length			50 percent span length		
		Mean	Range	Standard deviation	Mean	Range	Standard deviation
SIMULATED SAMPLE							
Not removed after each reading	50	0.8808	0.004	±.0011	0.4633	0.003	±.0007
Removed after each reading	50	.8820	.003	±.0008	.4632	.003	±.0006
Read over a 9-month period	96	.8821	.012	±.0049	.4639	.009	±.0066
ONE SPECIMEN OF HAND-COMBED COTTON							
First day	50	1.0280	.017	±.0046	.4463	.017	±.0041
Read 10 times a day for 5 days	50	1.0295	.029	±.0060	.4436	.010	±.0037
50 SPECIMENS OF CARD WEB							
Measured by Technician A	50	1.046	.044	±.0106	.4774	.061	±.0118
Measured by Technician B	50	1.045	.046	±.0120	.4696	.047	±.0106

TABLE 2.—*Digital Fibrograph and Suter-Webb array measurements of Series I and Series II samples of cotton*

Measurements	Lot means [1]			Sensitivity: CV of lot mean		Repeatability: CV of individual observations	
	Unit	Series I	Series II	Series I	Series II	Series I	Series II
				Percent	Percent	Percent	Percent
SUTER-WEBB ARRAY							
Upper quartile length	Inches	1.213	1.250	7.29	2.10	1.15	1.60
Coefficient of variation	Percent	30.56	30.60	13.06	8.41	4.18	2.87
Fibers shorter than ½-inch	Percent	9.6	9.3	36.78	21.60	11.60	8.85
DIGITAL FIBROGRAPH [2]							
2.5 percent span length	Inches	1.086	1.087	6.05	2.07	1.26	1.10
50 percent span length	Inches	0.477	0.461	6.59	4.30	2.77	2.68
66.7 percent span length	Inches	0.362	0.349	6.16	4.41	3.23	2.98
50/2.5 uniformity ratio	Ratio	43.88	42.33	4.27	2.37	2.36	2.45

[1] Number of observations per test: array, 3; Digital Fibrograph, 4.
[2] Values are from test 1.

When the range of length was small (Series II): (1) the 2.5 percent span length seemed to be a more efficient test than array UQL; (2) array CV was more efficient than the 50 or 66.7 percent span lengths or the 50/2.5 uniformity ratio; (3) the 50/2.5 uniformity ratio was the least efficient of the Digital measurements; and (4) array SF seemed to be a more efficient test than array CV or the corresponding Digital measurements.

Another method sometimes used for comparing tests is that of determining the number of specimens of one test required to equal one specimen of the other test:[5]

Measurements compared	*Estimated number of Digital specimens to equal one of array* — *Series I*	*Series II*
Array upper quartile vs. 2.5 percent span length	2	0.5
Array coefficient of length variation with—		
50 percent span length	2	3
66.7 percent span length	3	4
50/2.5 uniformity ratio	3	9
Array percentage of fibers shorter than ½ inch with—		
50 percent span length	2	2
66.7 percent span length	3	3
50/2.5 uniformity ratio	3	6

Both methods for comparing the efficiency of array and Digital Fibrograph tests show that the array test was more efficient than the Digital Fibrograph test, except for the 2.5 percent span length when testing a group of samples having a narrow range of length. The 50/2.5 uniformity ratio was the least efficient of the Digital measurements and was less valuable when range of length was small than when it was large.

A significant difference in level was found between technicians; however, the error was well within the accepted practical limits for standard check test samples. A difference in level is a common occurrence in fiber testing where the techniques are not completely objective.

A test was made to determine the fastest rate at which the Digital Fibrograph could be operated when actually measuring samples. The machine was not allowed to be idle; combs were replaced as soon as the machine had balanced. The average rate of speed was one specimen per minute for the 2.5 and 50 percent span length readings.

[5] GRAHAM, JOHN, and CARPENTER, FRANCES. EVALUATION OF A NEW AIR DEVICE FOR THE MEASUREMENT OF COTTON FIBER LENGTH AND LENGTH UNIFORMITY. Paper presented at Open House and Research Conference, A.T.M.I., Inc., Clemson. S.C., May 1963.

Relationship of Array, Servo, and Digital Fibrograph Measurements to Spinning Performance of Carded Yarn

Array data and corresponding Servo and Digital Fibrograph measurements were correlated with break factor and end breakage for 50s carded yarn and with spinning potential yarn number [6] from medium staple cotton (table 3). The analysis showed that (1) array mean length had higher correlation coefficients with spinning test results than any other length measurements; (2) the 2.5 percent span length was as good as, or better than, array UQL or Servo UHM in explaining variation in break factor and end breakage for the carded yarn; (3) each of the three Digital span lengths was better than array measurements at the 80 percent confidence level in explaining variation in the spinning potential yarn number; and (4) both array CV and SF and Digital span length measurements were significantly better than Servo UR (uniformity ratio) in explaining spinning end breakage.

TABLE 3.—*Relationship of array, Servo, and Digital Fibrograph measurements to spinning performance of carded cotton yarn (Series II samples)*

Independent variables	Simple correlation coefficients		
	Break factor of 50s yarn	EDMSH of 50s yarn [1]	Spinning potential yarn number
ARRAY			
Upper quartile length	+0.77	−0.66	+0.53
Mean length	+ .82	− .69	+ .57
Coefficient of variation	− .75	+ .65	− .51
SF [2]	− .79	+ .68	− .54
SERVO FIBROGRAPH			
UHM	+ .80	− .64	+ .70
Mean length	+ .65	− .61	+ .70
UR	+ .27	− .35	+ .39
DIGITAL FIBROGRAPH			
2.5 percent span length	+ .80	− .66	+ .77
50 percent span length	+ .74	− .64	+ .79
66.7 percent span length	+ .72	− .63	+ .77
50/2.5 UR	+ .58	− .47	+ .65

[1] EDMSH: Log_{10} for ends down per 1,000 spindle hours were used in the analyses.
[2] SF = Percentage of fibers shorter than 1/2 inch.

Evaluation of Experimental Values for Expressing Length Distribution

Several experimental values for length distribution were investigated using data from Series I and Series II samples. Length distribution from the fibrogram is difficult to express in a single value. It is possible for two samples to have the same 2.5 percent span length and have a very different distribution of length. It is generally conceded that a measurement at both ends of the samples is necessary to show this difference (*2*).

A perfect measure of length distribution obtained from the fibrogram would represent either (1) the area under the fibrogram or (2) the area between the fibrogram and a theoretical fibrogram of a sample having all of its fibers the same length (fig. 3). "Absolute" ratios (ratio between observed span lengths and span lengths for theoretical samples having perfect uniformity) at both the 50 percent and 66.7 percent span lengths were calculated. The relationship of these and other experimental values, as well as of the 50 percent and 66.7 percent span lengths to array CV, were compared for the Series I and Series II samples, and the relationship of the experimental values to array SF were compared for the Series II samples (table 4). Values that looked best for Series I samples did not seem

[6] "Yarn number calculated to produce 20 ends down per hour on 84 spindles" (*9*).

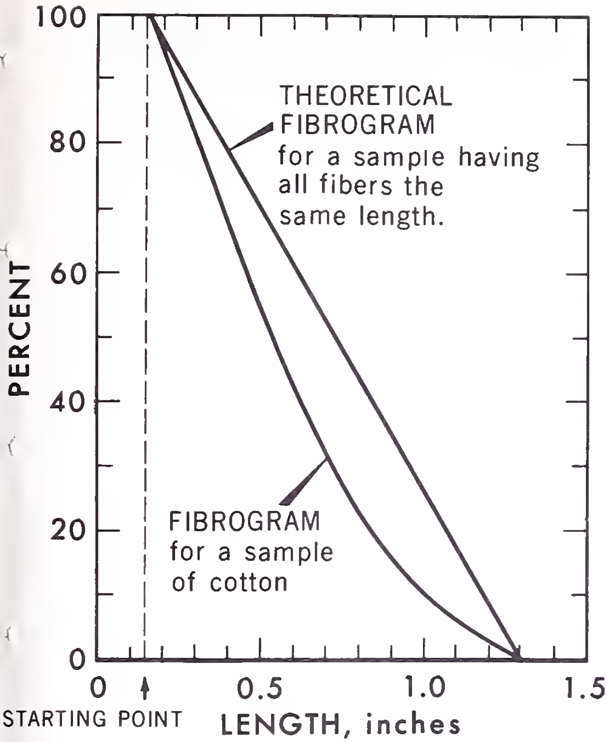

FIGURE 3.—Two ways to express length distribution.

TABLE 4.—*Simple correlation coefficients of the relationship of various Digital measurements with array coefficient of length variability and array percentage of cotton fibers shorter than ½ inch*

Variables	Series I, array CV	Series II Array CV	Series II Array SF
SERVO UR	---	−.468	−.406
DIGITAL			
50 percent span length	−.746	−.741	−.734
66.7 percent span length	−.778	−.732	−.724
50/2.5 UR	−.680	−.738	−.699
FFI [1]	.814	.731	.686
50 absolute ratio	−.761	−.696	−.638
66.7 absolute ratio	−.782	−.734	−.694
66.7/2.5 UR	−.613	---	---
$\frac{50 \text{ SL} - .150''}{2.5 \text{ SL} - .150''}$ ratio	−.832	−.708	−.660
Percent at 0.500 inch	−.811	−.764	−.746

[1] Floating fiber index $= \left[\frac{S_{2.5\%}}{3(S_{66.7\%} - 0.1)} - 1\right] \times 100$, where S = span length.

best for Series II samples. When the range of length was small it seemed that either the 50 percent or 66.7 percent span length was as closely related to array CV or array SF as any of the other measurements. It seemed that the Digital values were related slightly more to array CV than to array SF.

The real test of the value of any measurement of length distribution is its ability to explain spinning performance. A comparison of correlation coefficients for each of the experimental values for length distribution with break factor and end breakage for 50s carded yarn and with the spinning potential yarn number for the Series II samples showed that the 50 percent span length was as good as any of the experimental values used in the analyses in explaining spinning performance (table 5). The percentage of fibers at 0.500 inch was as good as the 50 percent span length in explaining break factor and end breakage.

It was thought that a combination of span lengths added together might be a useful measure of length distribution (table 5). It was found that either the 2.5 percent or the 50 percent span length alone was as good as any of the sums in explaining spinning performance. The 2.5 percent span length seemed slightly better than the 50 percent span length in explaining break factor.

These conclusions apply to data from samples having a narrow range of length. Other measures of length distribution might be more valuable for testing cottons with a wide range of length.

Multiple correlation analyses were made of the four Digital measurements and of array UQL, CV, and SF with break factor, spinning end breakage, and spinning potential yarn number for the Series II samples:

	Multiple correlation coefficients	
	Digital	*Array*
Break factor	.810	.823
Ends down per thousand spindle hours	.812	.708
Spinning potential yarn number	.677	.556

Array and Digital measurements were similar in explaining break factor. Digital measurements appear to be more adequate predictors of spinning end breakage and of spinning potential yarn number than the array measurements were.

TABLE 5.—*Simple correlation coefficients of the relationship of various length distribution values to spinning performance for Series II (carded yarn)*

Variables	Break factor of 50s yarn	EDMSH of 50s yarn (Log_{10})	Spinning potential yarn number
50 percent SL	0.744	−0.642	0.793
66.7 percent SL	.718	− .629	.772
50/2.5 UR	.581	− .472	.653
FFI	− .621	.582	− .664
50 absolute ratio	.567	− .518	.678
66.7 absolute ratio	.630	− .586	.715
$\frac{50\ SL-.150''}{2.5\ SL-.150''}$ ratio	.641	− .558	.718
Percent at 0.500 inch	.758	− .629	.681
Sum of 19 span lengths [1]	.785	− .682	.748
Sum of 4 span lengths [2]	.773	− .665	.752
Sum of 3 span lengths [3]	.776	− .656	.756
Sum of 2 span lengths [4]	.790	− .677	.768
2.5 percent span length	.796	− .661	.770

[1] Sum of 80, 66.7, 60, 50, 40, 30, 25, 20, 15, 12.5, 7.5, 5, 4, 3, 2.5, 2, 1.5, 1, 0.5 percent span lengths.
[2] Sum of 66.7, 50, 12.5, 2.5 percent span lengths.
[3] Sum of 66.7, 50, 2.5 percent span lengths.
[4] Sum of 50 and 2.5 percent span lengths.

Evaluation of Various Span Lengths

The meaning of measurements obtained on fiber beards by scanning is difficult to understand. The Fibrograph scans across the width of a fiber beard, at right angles to the length of the fibers, using a point 0.150 inch from the combs as a starting point. Percentage of fibers at any desired length, or length (span length) at any desired percentage point, may be obtained (fig. 4). If, for example, the 2.5 percent span length is desired, the combs holding the fiber beards are raised until the scanning device sees only 2.5 percent of the total number of fibers. The distance from the comb to this second scanning point is the 2.5 percent span length. It can be seen that 2.5 percent of the fibers in the beard at 0.150 inch extend this far or farther from the comb.

The manufacturer recommends the use of the 2.5 percent and 50 percent span lengths to describe length and length distribution and these lengths are almost universally used. A search of literature did not show why these span lengths were selected over all possible ones which can be made. The basis for their selection seems to have been mainly that the 2.5 percent span length agrees well with classers' length in level, and the 50 percent span length is near the short fiber region.[7] A few other lengths and starting points have been used, but not so successfully.

Nineteen span lengths were measured on specimens from Series II samples which had a narrow range of length. The data were analyzed by analysis of variance to find out which span lengths were the more efficient tests. As previously described, efficiency of test was deter-

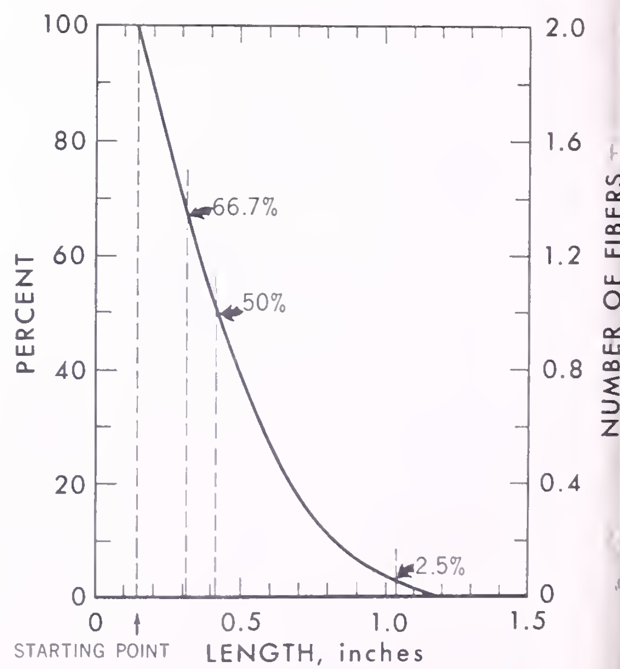

FIGURE 4.—The measurement of a fiber beard by scanning.

[7] See footnote 2.

mined by the ratio of sensitivity (CV of lot means) to repeatability (CV of error for individual observations). Six span lengths were selected for measurement of Series III samples. These data and those for three span lengths measured previously on Series I samples were analyzed in the same manner as those for Series II.

Repeatability varied for span lengths within a series but was similar for respective span lengths for the three series of samples studied (table 6).

Test efficiency varied primarily because of the range between lot means within each series of samples (fig. 5). Series I had a wide range of length, but all measurements had a common starting point, that of 0.150 inch. Measurements near the starting point were not as likely to vary widely as ones nearer to the unrestricted end of the fibrogram, that is, nearer the 2.5 percent span length. Sensitivity for the three span lengths measured was very similar, and since repeatability was better for the 2.5 percent span length, it was the most efficient of the three span lengths.

Series II samples had a very narrow range of length and a common starting point; in effect, the fibrograms were pulled together at the long end due to the selection of samples. Fibrograms for these samples were unrestricted between the two ends; hence, range of span lengths across samples was greater in this midsection than at the ends. Test efficiency was as good at the 50 percent span length as it was at the 2.5 percent span length. An examination of other span lengths between these two showed the 30, 20, and the 12.5 percent span lengths to be slightly more efficient tests than the 50 or the 2.5 percent span lengths.

Series III samples had a greater range in the 2.5 percent span lengths than Series II samples, the range being 0.148 and 0.091 inch, respectively. Span lengths in the same midsection as that of Series II, that is, from the 30 to 12.5 percent span lengths, inclusive, were slightly more efficient tests than those on either side of this section.

Simple correlation analyses were made of each of the 8 most efficient span lengths with spinning performance so that they could be compared. A comparison of the correlation coefficients shows that no one span length is better than another in explaining either break factor or spinning end breakage for the carded or the combed yarn (table 7). The same is true for spinning potential yarn number for the carded yarn. No data were available for spinning potential yarn number for the combed yarn.

It was shown previously that sums of span lengths were no better than one span length

TABLE 6.—*Range, means, and error CV for each of the three span lengths measured on Series I, II, and III samples of cotton*

Span lengths	Series I	Series II	Series III
66.7 PERCENT			
Range.........inches	0.100	0.057	0.099
Mean..........inches	.362	.349	.370
Error CV......percent	3.23	3.09	3.41
50 PERCENT			
Range.........inches	.138	.074	.124
Mean..........inches	.477	.461	.495
Error CV......percent	2.77	2.74	2.73
2.5 PERCENT			
Range.........inches	.257	.091	.148
Mean..........inches	1.086	1.087	1.154
Error CV......percent	1.26	1.40	1.58

TABLE 7.—*Simple correlation coefficients of the relationship of various span lengths to spinning performance of a medium staple and a long staple cotton*

Span lengths (percent)	Break factor		EDMSH		Spinning potential yarn No.; carded yarn, medium
	Carded yarn, medium	Combed yarn, long	Carded yarn, medium	Combed yarn, long	
80	0.683	0.698	−.590	−.624	0.684
66.7	.718	.761	−.629	−.623	.772
50	.744	.759	−.642	−.625	.793
30	.726	.759	−.612	−.629	.703
20	.740	.756	−.646	−.662	.715
12.5	.753	.754	−.675	−.607	.730
5.0	.802	.747	−.715	−.581	.738
2.5	.796	.746	−.661	−.549	.770

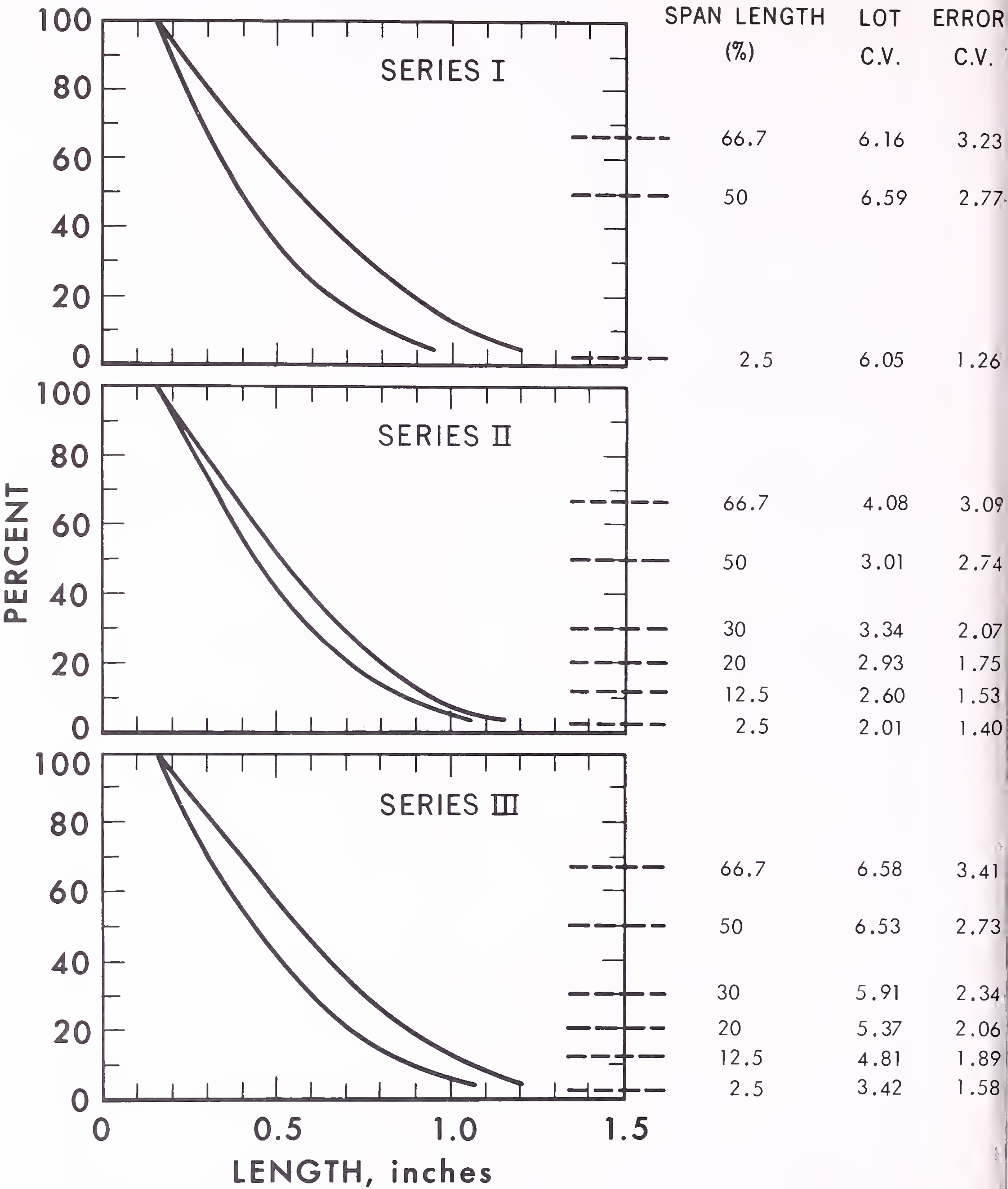

FIGURE 5.—Comparisons of fibrograms representing range at different span lengths for three series of samples.

alone and that one span length was as good as another in explaining variation in spinning. These results infer a high degree of relationship between span lengths. Simple correlation coefficients for pairs of adjacent span lengths were .99 and above for Series III samples. The relationship of the 2.5 percent span length to the 50 percent span length for the three series of samples shows that the selection of samples affects this relationship. The nature of the specimens used and the method for measuring them with the Digital Fibrograph give a built-in factor which is a major cause of the relationships described above. Each span length contains by number all of the fibers which extend that far or farther from the comb.

Digital Fibrograph for Measuring Ginned Lint, Card and Comber Slivers, and Comber Noils

It was found that the more or less standard measurements now in use in industry were as good in explaining variation in spinning as any of the experimental span lengths that were studied. Further comparisons of Digital Fibrograph measurements were made on the basis of the 2.5 and 50 percent span lengths and the 50/2.5 UR for ginned lint, card sliver, comber sliver, and comber noils on 69 lots of Series III.

There was a progressive increase in the 2.5 and 50 percent span lengths with increased processing (table 8). Array UQL and mean length did not follow this same pattern, but decreased from ginned lint to card sliver. The array measurements show the effect of more short fibers in the card sliver than the Digital Fibrograph measurements show.

Array measurements of length of comber noils were more sensitive to sample differences than the 2.5 percent span length, but the 50 percent span length and the 50/2.5 UR were more sensitive to sample differences than array CV.

Testing errors, as determined by analyses of variance of the Digital 2.5 and 50 percent span lengths, expressed as the coefficient of variation for error, are as follows:

	Error CV for span lengths 2.5 percent	*50 percent*
	Percent	*Percent*
Ginned lint	1.58	2.73
Card sliver	1.24	2.80
Comber sliver	1.70	3.67
Comber noils	2.27	2.13

The above results indicate that tests for the comber sliver varied more than those for ginned lint or card sliver. The higher testing error in comber sliver was probably due to the difficulty encountered in obtaining representative specimens from highly parallelized fibers. Successful specimen preparation with the Fibrosampler depends upon random alinement of the fibers in the sample. Although an effort was made to disorient the fibers in the sliver many of the specimens measured had thick and thin places

TABLE 8.—*Means and coefficients of variation for the corresponding array and Digital Fibrograph measurements of ginned lint, card and comber slivers, and comber noils*

Length measurements	Mean					Coefficient of variation			
	Unit	Ginned lint	Card sliver	Comber sliver	Comber noils	Ginned lint	Card sliver	Comber sliver	Comber noils
						Percent	*Percent*	*Percent*	*Percent*
ARRAY									
UQL	Inches	1.335	1.304	1.307	0.772	1.98	2.80	2.65	8.92
Mean length	Do.	1.101	1.030	1.077	.565	4.41	5.17	4.23	7.08
CV	Percent	30.04	34.54	28.77	58.64	9.92	8.77	8.13	2.54
SF [1]	Do.	91.86	88.37	93.40	52.11	2.49	3.45	2.25	7.41
DIGITAL									
2.5 percent SL	Inches	1.155	1.181	1.214	.874	2.50	2.46	2.77	4.83
50 percent SL	Do.	.495	.522	.590	.308	4.75	5.65	5.40	2.89
50/2.5 UR	Ratio	42.9	44.2	48.5	35.3	2.56	4.28	3.03	2.63

[1] Percentage of fibers longer than ½ inch for the 3 stages of processing and shorter than ½ inch for comber noils.

which caused error. The small testing error for comber noils was due in part to samples having very little fiber alinement.

Simple correlation analyses were made of the relationship of each of the length measurements for ginned lint, card sliver, and comber sliver to break factor and to spinning end breakage. Comparisons of the simple correlation coefficients for the three kinds of samples (table 9) show that:

(1) Digital span lengths explain as much of the variation for the break factor as the corresponding array length measurements.

(2) At any of the three stages of processing, Digital 50/2.5 UR does not seem to be as good as the span lengths or array CV or SF in explaining break factor.

For spinning end breakage, Digital and array measurements of length distribution of ginned lint seemed to be of almost equal significance in explaining variation. But array SF measurements for card sliver and for comber sliver were better than the Digital 50/2.5 UR (95 percent level of significance), and array SF and CV were better than the 50 percent span length for comber sliver (90 percent level of significance).

TABLE 9.—*Simple correlation coefficients of the relationship of corresponding array, Servo, and Digital Fibrograph measurements to break factor and end breakage for 60s combed cotton yarn*

Length measurements	Ginned lint		Card sliver		Combed sliver	
	Break factor	EDMSH	Break factor	EDMSH	Break factor	EDMSH
ARRAY						
UQL	+0.709	−0.469	+0.729	−0.603	+0.742	−0.604
Mean length	+ .794	− .584	+ .771	− .662	+ .781	− .687
CV	− .758	+ .667	− .751	+ .677	− .709	+ .741
SF [1]	+ .769	− .694	+ .735	− .730	+ .724	− .774
DIGITAL						
2.5 percent SL	+ .746	− .549	+ .775	− .649	+ .734	− .553
50 percent SL	+ .759	− .625	+ .767	− .629	+ .715	− .572
50/2.5 UR	+ .694	− .647	+ .691	− .573	+ .630	− .546

[1] Percentage of fibers longer than 1/2 inch for the 3 stages of processing.

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